# Exploring Relationships Among Macrocognitive Processes with a Card Sort Study

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This study examines how study participants with no prior knowledge of a set of macrocognitive processes grouped the concepts, defined their categories, and distinguished among groups. The findings from this study both support and extend prior findings about the existence of a set of macrocognitive processes and their interrelationships. In future work, we plan on exploring more systematically how these data relate to two conceptual frameworks published in the macrocognition literature.

# INTRODUCTION

In prior research, a number of proposed macrocognitive processes have been empirically identified, primarily via coding of verbal transcripts, in a number of laboratory and field settings ((Letsky, Warner, Fiore, & Smith, 2008; Warner, Letsky, & Cowen, 2005). In this paper, we describe a card sorting study that examines how study participants with no prior knowledge of these processes group the concepts and define relationships across groups. Finally, we identify repeating patterns across study participants that suggest common distinctions among types of processes. In future work, we plan on exploring how different conceptual models of macrocognition map onto these findings.

In their conceptual framework for macrocognition (which differs from other definitions of macrocognition such as Klein et al., 2003), Warner, Letsky, and Cowen (2005) argued that macrocognition in teams encompasses both internalized and externalized processes, which occur during team interaction. Macrocognition is defined as the internalized and externalized high-level mental processes employed by teams to create new knowledge during complex, one-of-a-kind, collaborative problem solving. High-level is defined as the process of combining, visualizing, and aggregating information to resolve ambiguity in support of the discovery of new knowledge and relationships. These processes can become either fully or partially externalized when they are expressed in a form that relates to other individual's reference/interpretation systems (e.g. language, icons, gestures, boundary objects).

# METHOD

A card sorting technique was used for this study (Rugg and McGeorge, 1997).

Two pilot runs were conducted using a single card sort with 29 cards. On the front of the card was the name of the macrocognitive process (e.g., Individual information gathering) and on the back of the card was the official definition from the literature (e.g., Actions individuals engage in to add to their existing knowledge such as reading, asking questions, accessing displays, etc.).

The methods were significantly modified following the pilot runs. Two card sorts were employed rather than one. The concept wording was shortened and simplified, the labels were removed, student-relevant examples were added for every concept. All data were displayed on the front of the card to ensure that all study participants were aware of all of the information without flipping over the cards (see Tables 1 and 2).

Table 1. Data for card sort #1

| Concept | Example |
|---|---|
| Acting to add to existing knowledge | Read a book, look at a map |
| Synthesizing information to see relationships between concepts | Look at class descriptions and list pros and cons for different options to satisfy requirements |
| Creating diagrams or table | Make a spreadsheet for which classes to take which quarter in order to graduate on time |
| Passing relevant information to the right person at the right time | A teammate points out that the room that they want to meet in will be locked on Sunday |
| Sharing | A teammate tells the team that |

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| explanations and interpretations with the team | the professor emailed him back that they can have an extra day for the project |
| Offering potential solutions to the team | A teammate suggests going to Kinko's to make color copies of the presentation for the professor |
| Clarifying and discussing pros and cons of potential solutions | One solution is to go to Kinko's to make color copies of the presentation for the professor, but we have to pay. Another solution is to do it here in black and white, which is quicker and free. |
| Critiquing the team's process of solution after getting feedback | The team lost 10 points on the grade because they went 10 minutes longer than allotted for their presentation. Everyone agreed that they should have only had one presenter and then have the entire team answer questions. |

Table 2. Data for card sort #2

| **Concept** | **Example** |
|---|---|
| How much everyone understands their roles and the roles of the others on the team, and how much everyone understands the critical goals and locations of resources | Everyone knows what the homework assignment is, who is supposed to do what, and what the name of the Powerpoint file is for the presentation |
| How much everyone agrees on procedures and resources to do a team task | All five team members knew that they were going to leave on their cellphones so that they could coordinate while driving two cars to the science fair |
| How much everyone on a team knows their roles and how to interact with each other | Greta's teammates all knew she had an IPhone that she could use to look up a location on a map while they were driving by typing in the address. |

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| How much everyone on a team agrees on the skill, knowledge, experience, dispositions and/or habits of the others | The team gave Bill the task of performing the statistical analysis for the project because he got an A in statistics. |
| How much everyone on a team is aware of moment-to-moment changes and agree on what the implications are | The team realized that they could not launch their rocket until the rain stopped |
| A team's collective understanding of resources and responsibilities associated with a task | Jill was the only one who knew that they had to keep original gas receipts to be reimbursed, but she didn't tell Joe when he filled the tank |
| Accurate knowledge held by team members that is useful for a task | Jim knew that only four students could fit in each car that the team had. |
| How much everyone has accurate knowledge of team roles, goals, responsibilities, access to information, constraints, and when to interact with other team members | The team expected Barb to tell Jodi when she was available to meet, so that Jodi could then schedule a room with the department secretary and then tell Tim, the leader, who would let everyone on the team know where and when to meet. |
| How much everyone has an accurate knowledge of the expertise and behavioral habits of all their team members | John knew that Bill used to design websites and is always five minutes late to meetings |
| How much an individual has an accurate awareness of moment-to-moment changes in the environment | Julia knew that it started raining ten minutes ago |
| Facts, relationships, and concepts that have been explicitly agreed | Everyone on the team agrees that there is 68 miles to drive to the |

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| upon by team members | science fair because Joe mapped a route starting from their school to the fair using Google maps |
| How much everyone agrees on their task strategies and what events should change those strategies | The team agreed that if it rained they would have to wear rain ponchos to the test site. |
| How accurate patterns and trends identified by team members are | Jill remarked that there are 5 bullets on every slide in the presentation and no one pointed out that actually that was only true for two slides and that, in fact, 3 slides had 3 bullets on them. |
| How much everyone agrees on the status of a problem | Everyone agrees that heavy rain makes it impossible to launch the rocket |

Study participants were recruited via IRB-approved procedures and data were collected in a single one-hour session. Study participants were monetarily compensated ($25) for participation.

# RESULTS

Sixteen study participants participated. The data were collected over an 8-week period in the winter quarter of 2009. 13 undergraduate students and 3 graduate students participated, representing 11 from Industrial and Systems Engineering, 3 from International Studies, 1 from anthropology, and 1 from biomedical engineering.

The primary data collected were the labels for the card groupings generated by the study participants. One investigator (JB) used a bottom-up approach to uniquely code every label into one of the emerging categories. Table 3 reports the number of study participants who employed one of these labels in explaining what distinction was employed for grouping a collection of cards separately from the others in either sort.

Table 3. Number of 16 participants employing a category

| **Category label** | **No.** |
|---|---|
| Exchanging thoughts and ideas | 10 |
| Teamwork activities/team working together | 9 |
| Team agreement on knowledge and information | 9 |
| Individual activities | 8 |
| Analysis of information | 8 |
| Awareness of patterns, trends and environment | 8 |
| Understanding of how team works | 8 |
| Passing information without added context | 7 |
| Making a decision | 7 |
| Knowing other team members' skill sets and role | 6 |
| Gaining knowledge | 5 |
| Individual expertise | 5 |
| Team members communicating | 4 |
| Prework to working with team | 4 |
| Actions | 4 |
| Relevance to success of team | 4 |
| Timing of information | 3 |
| Information organization | 3 |
| Knowledge about task/project status | 3 |
| Data/facts/knowledge | 3 |
| Planning | 3 |
| General agreement | 3 |
| Team unity/togetherness | 3 |
| Evaluation by/of team | 3 |
| Accuracy of knowledge/understanding | 3 |
| Displaying information | 2 |

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| Problem solving in team setting | 2 |
| Team agreement about information/knowledge | 2 |
| Assumed knowledge | 2 |
| Activities near the end of a project | 2 |
| Coming up with potential solutions | 2 |
| Evaluating potential solutions | 2 |
| Evaluation by/of individual | 2 |
| Based on word patterns in examples | 2 |
| Evaluation | 1 |
| Early stages of teamwork | 1 |
| Chronology of teamwork | 1 |
| Ambiguous information sharing | 1 |
| Accurate understanding of roles/agreement | 1 |
| Activities for a data driven person | 1 |

Each of the category labels in Table 3 were printed out and grouped by both investigators working together into emerging distinctions between categories. This activity generated the list of distinctions in Table 4. One investigator (JB) then re-analyzed the data for the number of study participants who employed each distinction in explaining how piles of cards related to other piles of cards for any of the sorts. The findings are reported in Table 4.

Table 4. Number of 16 participants employing a distinction

| **Distinction in Relationships Between Piles** | **No.** |
|---|---|
| Team vs. individual | 12 |
| High vs. low dissension | 12 |
| Analysis vs. synthesis | 11 |
| High vs. low knowledge specialization | 11 |
| Analysis vs. planning vs. acting | 9 |
| Sharing vs. working | 9 |
| High vs. low clarity in roles (who does what) | 8 |
| Early vs. late collaboration stages | 8 |
| Generating vs. evaluating | 4 |
| High vs. low information organization | 4 |
| High vs. low team unity | 3 |
| High vs. low information accuracy | 3 |

# DISCUSSION

The findings from this study both support and extend prior findings about the existence of a set of macrocognitive processes and their interrelationships. The findings suggest that distinctions represented in many conceptual frameworks for collaborative activities are widely believed to exist, even among study participants with little to no prior knowledge of the literature on macrocognition.

Although a significant limitation of this study is the use of undergraduate and graduate students as study participants with no significant expertise in a particular task domain, all of the students had prior experience working on teams, could relate to the examples that were provided to the them, and their lack of knowledge about the particular macrocognitive processes that were studied reduced the chance for biased findings towards any particular conceptualization.

In future work, we plan on exploring more systematically how the identified distinctions map onto distinctions embedded in two conceptual frameworks for macrocognition (Warner et al., 2005 and Patterson & Hoffman, in preparation).

Only a portion of the Warner et al., 2005, framework is graphically represented in Figure 1. In this figure, four non-sequential, dynamic collaborative stages are represented (Warner et al., 2005):

- *Knowledge Construction* begins by identifying the relevant domain information required, selecting the required team members, setting up the communication environment necessary to address the problem, individual team members developing their own mental model of the problem, and developing individual and team task knowledge.

- *Collaborative Team Problem Solving* is where the majority of collaboration occurs among team members. The team's main objective in this stage is to develop viable solutions to the problem.
- *Team Consensus* is to achieve team agreement among several viable solution alternatives to the problem.
- *Outcome Evaluation and Revision.* The main objective of this stage is to analyze, test and validate the agreed upon team solution against the goal requirement(s) and exit criteria. Included in this stage is an iteration loop for deriving other solutions for the problem if necessary.

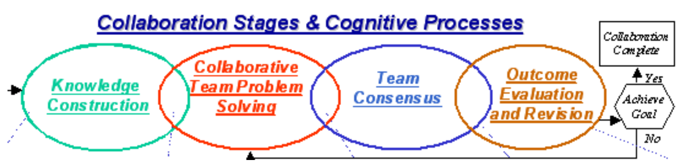


Figure 1. Structural model of team collaboration (from Warner et al., 2005)

In Figure 2, proposed relationships among non-sequential, simultaneous macrocognitive functions described in Klein et a., 2003 are graphically represented. These relationships (Patterson and Hoffman, in preparation) highlight:

- how coordinating is an infrastructure function supporting all other macrocognitive functions
- how the level of commitment to decisions changes over time and impacts the status of macrocognitive functions
- how detailed analysis (assessing explanations) relates to “stepping back” to looks for gaps and use a wider scope (making sense)

- how assessing explanations, replanning, and executing plans are central, overlapping, and yet distinguishable macrocognitive functions and how they relate
- how detecting anomalies in the environment impacts more self-paced macrocognitive functions

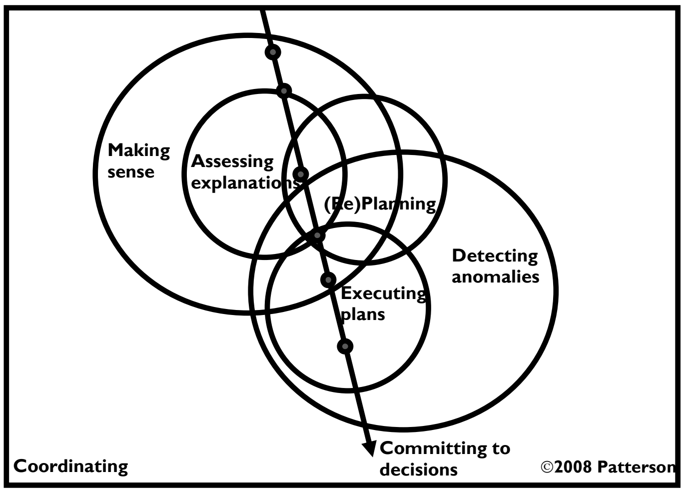


Figure 2. Graphical representation of relationship among macrocognitive functions

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